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Experimental Investigations of EDM Parameters

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Abstract: - Electric Discharge Machining is capable of machining geometrically complex or hard material components, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries.. The objective of this paper is to study the influence of operating parameters like current, voltage, pulse-on time and pulse-off time for responses such as Material Removal Rate (MRR) and Surface Roughness (Ra) on the EDM of WPS DIN 1.2379/AISI D2 tool steel using the copper electrode material. The effectiveness of EDM process with WPS DIN 1.2379/AISI D2 is evaluated in terms of the Material removal rate and Surface roughness produced. Design of experiment is conducted with L9 orthogonal array and Multi-objective optimization is carried out with the help of Response surface methodology to optimize both the responses at the same time and it was found that current is the more influential parameter affecting the material removal rate and surface roughness.

Keywords:- Electrical discharge machining, Material Removal Rate, Surface roughness, Response Surface Methodology, Design of Experiments.

I. INTRODUCTION

Electrical discharge machining sometimes colloquially also referred as spark machining, spark eroding, burning, die sinking or wire erosion is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Material is removed from the workpiece by means of a series of repeated recurring electric discharges between tool electrode and workpiece separated by a dielectric fluid and subject to an electric voltage. Electrical discharge machining (EDM) is a manufacturing method which could be used to machine hard materials in complex shapes with high precision. EDM is commonly used in aerospace industries, die and injection mold manufacturing across the world. The research in EDM machining is generally focused on maximum material removal rate with good surface finish and less tool wear. It has been classified in four groups mainly workpiece related, different electrode material used, effective EDM methods, and optimization of EDM parameters. High carbon high chromium steel offers good dimensional accuracy, wear resistance and machinability. In this paper an attempt has been made to study the various effects of discharge current, pulse-on time, pulse-off time and gap voltage on responses like MRR and SR with the help of WPS DIN 1.2379/AISI D2 tool steel as workpiece material and copper as a tool electrode . Taguchi method of design of experiment is conducted with L9 orthogonal array and multi- objective optimization is carried out with the help of Response surface methodology to optimize both the MRR and SR at the same time.

The objectives of this paper are stated as follows:

a) To evaluate the performance of process parameters like I_P, T_{on}, T_{off}, V_g with the help of copper electrode on high carbon high chromium (WPS DIN 1.2379/AISI D2) with respect to various response parameters like the material removal rate (MRR) and surface roughness (Ra) .

b) Taguchi method of design of experiment is conducted with L9 orthogonal array and Multi-objective optimization is carried out with the help of Response Surface Methodology (RSM) to optimize both MRR and SR at the same time.

II. LITERATURE SURVEY

A. Soveja et al [1] has defined the experimental study of the surface laser Texturing of TA6V alloy. The influence of the operating factors of the laser Texturing process has been studied using two experimental approaches: Taguchi methodology and RSM .Empirical models have been developed . They allowed us to determine a correlation between process operating factors and performance indicators, such as surface roughness and MRR. Results analysis shows that the laser pulse energy and frequency are the most important operating factors. Mathematical models, that have been developed, can be used for the selection of operating factors, proper values in order to obtain the desired value of the objective functions.

Puertas and Luis [2] have defined the optimization of machining parameter for the EDM of Boron carbide of conductive ceramic materials. It is these conditions that determine such important characteristics as surface roughness, electrode wear, and MRR. In this article, a review of state of the art of the die sinking EDM processes for conductive ceramic materials, as well as a description of the equipment used for carrying out the experiments, are presented. Also, a series of mathematical models will be devised using design of experiments techniques combined with multiple linear regression, which will allow us, while only performing a small number of experiments, to select the optimal machining conditions for the finishing stage of the EDM process.

Sameh S. Habib [3] have defined the experimental study of machining parameters like MRR, TWR, gap size and SR and relevant experimental data were obtained through experimentation by using RSM. They are using Al/SiC composite material and shown the correlations between the cutting rates, the surface finish and the physical material parameters was obtained in achieving controlled EDM of the workpiece and finding the MRR increases with an increase of pulse-on time, peak current and gap voltage and MRR decrease with increasing of SiC%.

K. Palanikumar [4] have defined experimental study of surface roughness through (RSM) hacking machining glass fiber reinforced plastics composites.Four factors five level central composites, rotatable design matrix is employed to carry out the experimental investigation. ANOVA is used to check the validity of the model. Also, on an analysis of the influences of the entire individual input machining parameters on the response has been carried out.

III. EXPERIMENTAL DETAILS

The material used in these experiments was WPS DIN 1.2379 tool steel material having size 10x40x40 mm with square shaped copper tool with 10x10x30 mm dimensions were used. Separate workpiece is used for each experiment using copper as an electrode tool and commercial grade EDM oil (specific gravity=0. 763, freezing point=94^{o}C) is used as a dielectric fluid. Square shaped copper electrode with EDM Oil is used to flush away the eroded materials from the sparking zone. In this machining time and duty cycle is kept constant is 30 mins and 0.75. For four factors are tackled with a total number of 9 experiments for copper electrode were performed. Electrical discharge machine (EDM) was used to machine on the workpiece for conducting the experiments. This machine model E46PM (die-sinking type) as shown in Fig.1.

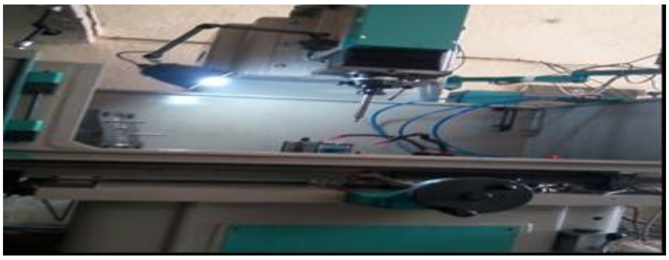

Fig 1 E46PM EDM machine

Fig .2 Workpiece after machining

Category	STEEL
Class	Cold work high carbon high chromium tool steel

Table I. WPS tool steel category

	Properties
Density	7.70 x 10^3 kg/m^3
Thermal conductivity	40.9-55.2 x10^{-3} cal/cms^{o}c
Elastic Modulus	173-193Gpa

Table II. Mechanical properties of WPS tool Steel

IV. RESULTS AND DISCUSSIONS

The analysis was made using the MINITAB 16 software specifically used for the design of experimental applications. This study uses four three levels L9 orthogonal array of design of experiments .

The coefficients of the model for MRR as shown in the table III-A . The parameters R2 describes the amount of variation observed in MRR is explained by the input factors R2=98. 34%, indicates that the model is able to predict the responses with high accuracy. Adjusted R2 is a modified R2 that has been adjusted for the number of terms in the model.If unnecessary terms are included in the model, R2 can be artificially high, but adjusted R2 (96.65%) may get smaller .The standard deviation of errors in the modeling is S=0. 0194208.

ANOVA for MRR of copper electrode for the factors shown in the table III-A clearly indicates that I_p has the greatest influence on material removal rates, followed by T_{on}, T_{off}, and V_g. The P-values for I_p , T_{on}, T_{off} and V_g are 0.000,0.387,0.429 and 0.646 respectively as shown in the table III-B.

Table III-A Estimated Model coefficients for MRR for copper electrode

Term	Coef	SE Coef	T	P
Constant	-0.083795	0.049462	-1.694	0.165
I_p	0.060236	0.004134	14.572	0.000
T_{on}	0.000157	0.000162	0.970	0.387
T_{off}	-0.001777	0.002020	-0.880	0.429
V_g	-0.000464	0.000937	-0.495	0.646

Summary of the model: - **S = 0.0194208, R-Sq = 98.34%, R-Sq (adj) = 96.69%**

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Regression	4	0.089547	0.089547	0.022387	59.35	0.001
Linear	4	0.089547	0.089547	0.022387	59.35	0.001
$\mathbf{I_p}$	1	0.088768	0.080084	0.080084	212.33	0.000
$\mathbf{T_{on}}$	1	0.000445	0.000355	0.000355	0.94	0.387
$\mathbf{T_{off}}$	1	0.000241	0.000292	0.000292	0.77	0.429
Vg	1	0.000093	0.000093	0.000093	0.25	0.646
Error	4	0.001509	0.001509	0.000377		
Total	8	0.091055				

Table III-B Analysis of Variance for MRR for Copper electrode

The coefficients of the model of Ra as shown in the table III-C. The parameters R2 describes the amount of variation observed in Ra is explained by the input factors R2=97. 82%, indicates that the model is able to predict the responses with high accuracy. Adjusted R2 is a modified R2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R2 can be artificially high, but adjusted R2 (95.63%) may get smaller .The standard deviation of errors in the modeling is S=0. 267917.

ANOVA for Ra of copper electrode for the factors shown in the table III-C clearly indicates that I_p has the greatest influence on surface roughness (SR), followed by T_{on}, V_g,and T_{off}. The P-values for I_P, T_{on}, T_{off} and V_g are 0.000,0.008,0.166 and 0.170 respectively as shown in the table III-D.

Table III-C Estimated Model coefficients for R_a for copper electrode

Term	Coef	SE Coef	T	P
Constant	1.83468	0.682348	2.689	0.055
I_p	0.63429	0.657028	11.122	0.000
T_{on}	0.01084	0.002230	4.860	0.008
T_{off}	-0.04663	0.027870	-1.673	0.170
V_g	-0.02190	0.012933	-1.694	0.166

Summary of the model: - **S =0. 267017, R-Sq = 97.82%, R-Sq (adj) = 95.63%**

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Regression	4	12.8550	12.8550	3.21374	44.77	0.001
Linear	4	12.8550	12.8550	3.21374	44.77	0.001
$\mathbf{I_p}$	1	10.5073	8.8798	8.87981	123.71	0.000

T_{on}	1	2.0068	1.6956	1.69562	23.62	0.008
T_{off}	1	0.1350	0.2009	0.20090	2.80	0.170
V_g	1	0.2059	0.2059	0.20581	2.87	0.166
Error	4	0.2871	0.2871	0.07178		
Total	8	13.1421				

Table III-D Analysis of Variance for Ra for Copper electrode

OPTIMIZATION PLOT

a) Table III-E shows the Optimal values of I_P, T_{on}, T_{off} and V_g are 6 A, 50µs,12 µs and 40 V respectively.

b) The optimization plots show us that I_P is the most influential parameter , as the I_P increases MRR and SR also increases, which is followed by T_{on},T_{off} and V_g for MRR and T_{on},V_g and T_{off} for SR respectively

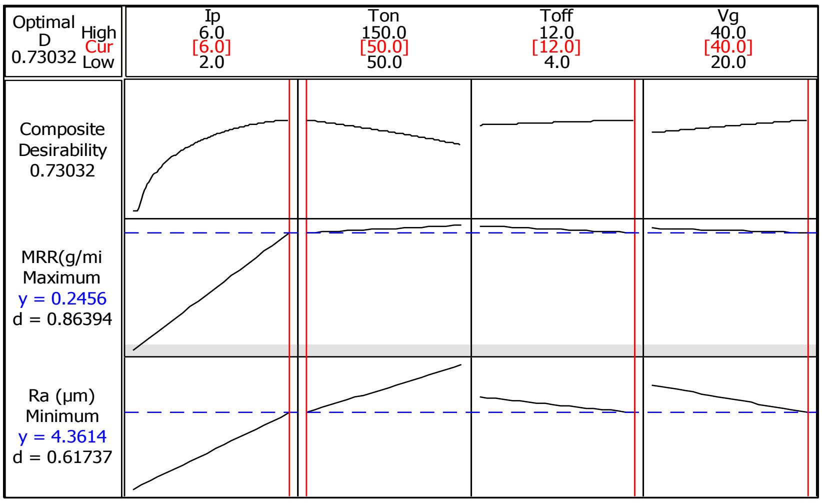

Table III-E Optimization plot for Copper electrode

IV. CONCLUSIONS

Basically this investigation is successful in achieving the objective with the acceptable outcome. This experiment evaluates the machining of WPS DIN 1.2379/ AISI D2 tool steel with a Copper as Electrode. The Taguchi method Design of experiment (DOE) is very useful in the analyzing the optimum condition of parameters, and the significance of individual parameter to Material removal Rate and Surface Roughness.

In the case of the of material removal rate, it was seen that current factor was the most influential, followed by and pulse-on time, pulse-off time and gap voltage. In order to obtain high material removal rate in the case of WPS 1.2379 DIN/AISI D2, within the work interval considered in this study, one should use, high values for current and gap voltage is to be used.

Finally, in the case of Surface Roughness , it was observed that the most influential factor was current, followed by a pulse-on time, gap voltage and pulse-off time. Therefore, in order to be able to obtain low values of surface roughness, low values of pulse-on time, current and gap voltage is to be used.

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